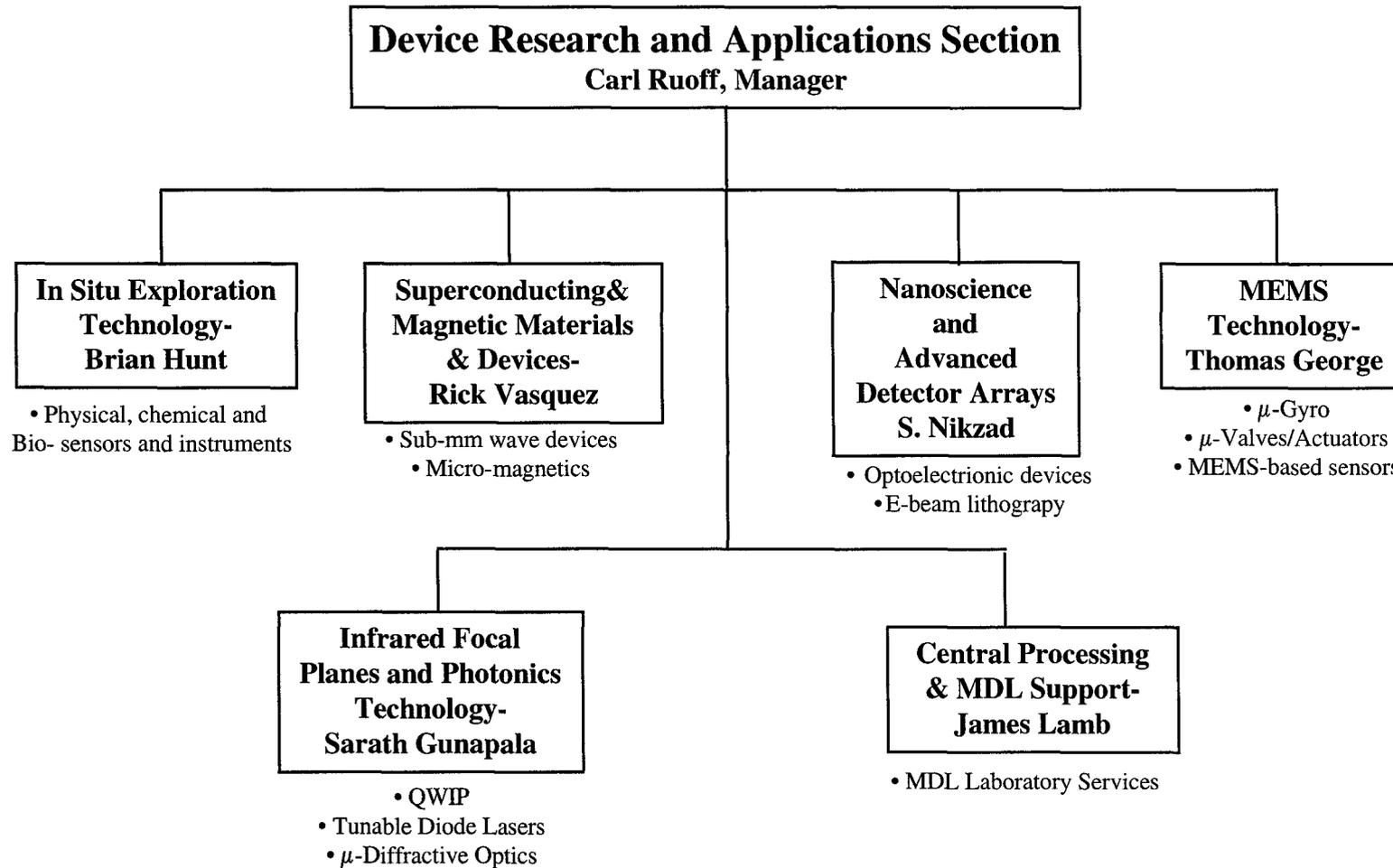
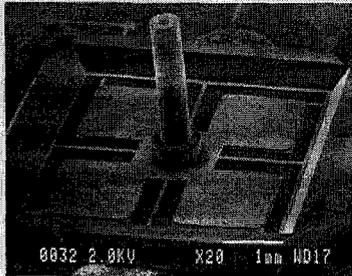


# Microdevices Lab and Nanotube Overview

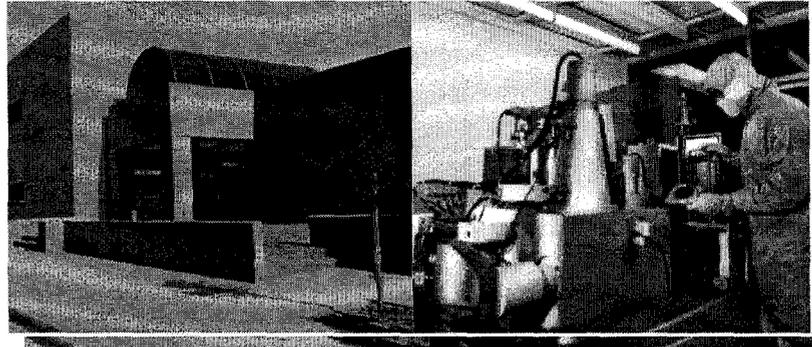


## Microinstruments and MEMS devices



- Surface / Bulk / LIGA micromachining
- Microinstruments including
  - $\mu$ -seismometer
  - micro gyroscope
  - micro weather station
  - electronic nose
  - micro propulsion

## Microdevices Laboratory (MDL)

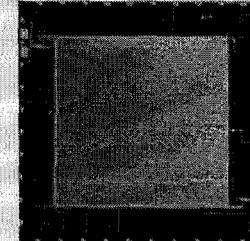


The Microdevices Laboratory (MDL) is a state of the art facility focused on creating the building blocks enabling NASA's vision of smaller, faster, cheaper spacecraft

MDL Facilities include: Class 10 cleanroom; E-beam and optical lithography; MBE, MOCVD, LPCVD growth systems; RIE systems; and full processing and characterization capabilities

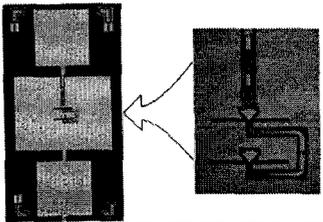
For more information: <http://csmt.jpl.nasa.gov/csmtpages/index.html>

## Infrared & Ultraviolet Focal Plane Arrays



- Quantum well Infrared photodetector (QWIP) arrays based on GaAs/AlGaAs
- Enhanced UV / X-ray CCDs via MBE  $\delta$ -doping
- Micromachined thermal infrared detector arrays
- GaN growth & devices

## Superconducting Devices



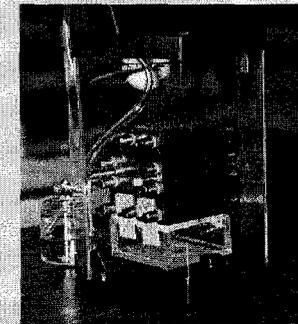
- Mixer arrays for sub-mm astronomy and atmospheric chemistry
- SIS and hot electron bolometer mixers
- Far infrared bolometers
- Lo- $T_c$  and hi- $T_c$  materials and devices

## Photonic Systems

- Tunable diode lasers for spectroscopy
  - Narrow linewidth
  - Ambient temperature
  - $\lambda$  out to 2.06  $\mu$ m
- Laser arrays for high rate communications (10's GB/sec)
- Laser metrology systems for optical & radar interferometers
- Integrated optoelectronics
- Unique diffractive optics



## Power Generation & Storage



- Lithium Battery Development
- Thermoelectric Materials
- AMTEC
- Advanced Solar Cells
- Direct Methanol Fuel Cells



## In Situ Exploration Technology

### Brian Hunt, GS

Bronikowski, Mike  
Buehler, Martin  
Cardell, Greg  
Choi, Dan  
Feldman, Jason  
Grannan, Sabrina  
Grunthaner, Frank  
Hoenk, Michael  
Kowalczyk, Bob  
Kuhlman, Kim  
Noca, Flavio  
Orient, Otto  
Pike, Tom  
Svehla, Danielle  
Taylor, Maggie  
Williams, Roger

- **Research and development of novel sensors, devices, and instruments relevant to unmanned and manned solar system exploration**

Long range  
research with  
broad focus

Prototype  
sensor and  
instrument  
development

Flight or  
near-flight  
instruments



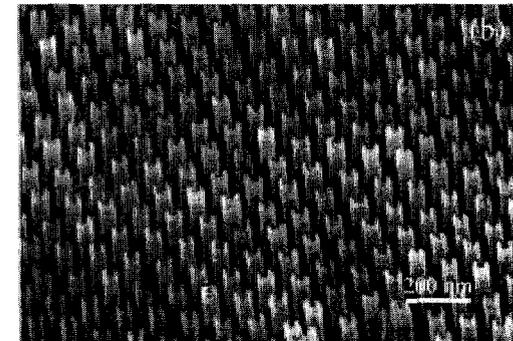
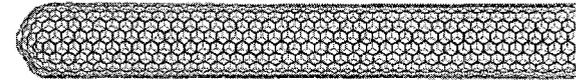
<ul style="list-style-type: none"><li>• <b>Nanotechnology-based sensors, devices, and instruments</b> (carbon nanotubes etc.)</li></ul>	<ul style="list-style-type: none"><li>• M. Bronikowski, D. Choi, M. Hoenk, F. Noca, B. Hunt, R. Kowalczyk, R. Williams</li></ul>
<ul style="list-style-type: none"><li>• <b>Microfluidics / <i>in situ</i> chemistry systems</b></li></ul>	<ul style="list-style-type: none"><li>• Sabrina Grannan, P&amp;F Grunthaner, D. Svehla, R. Williams</li></ul>
<ul style="list-style-type: none"><li>• <b>In Situ Geochronology Instrument</b></li><li>• <b>LIDAR, Pulsed Fiber Laser</b></li></ul>	<ul style="list-style-type: none"><li>• Greg Cardell, Maggie Taylor</li></ul>
<ul style="list-style-type: none"><li>• <b>Miniature Local Electrode Atom Probe (Mini-LEAP)</b></li></ul>	Kim Kuhlman, Bob Kowalczyk
<ul style="list-style-type: none"><li>• <b>Chemical AFM</b></li></ul>	<ul style="list-style-type: none"><li>• Tom Pike, Mark Anderson (353), et al.</li></ul>
<ul style="list-style-type: none"><li>• <b>Microseismometer for Netlander '07</b></li></ul>	<ul style="list-style-type: none"><li>• Tom Pike, Dan Choi et al.</li></ul>

<ul style="list-style-type: none"> <li>• <b>Microweather station / hygrometer</b></li> </ul>	<p>Michael Hoenk, Flavio Noca, Greg Cardell</p>
<ul style="list-style-type: none"> <li>• <b>Cryobot and sensor web development</b></li> </ul>	<p>Jason Feldman et al.</p>
<ul style="list-style-type: none"> <li>• <b>E-Tongue/Water quality monitor</b></li> </ul>	<ul style="list-style-type: none"> <li>• Martin Buehler, Greg Kuhlman (354)</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Atmospheric Electron X-ray spectrometer</b></li> </ul>	<ul style="list-style-type: none"> <li>• Jason Feldman, Thomas George, Jarka Wilcox</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Mars Organic Detector (MOD), Mars Oxidation Instruments (MOI, MAOS)</b></li> </ul>	<ul style="list-style-type: none"> <li>• Frank Grunthaner, Martin Buehler, Bob Kowalczyk, et al.</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Mars Environmental Compatibility Assessment (MECA) flight project</b>              –Wet chemistry cells, electrometer, optical/AFM microscopy, patch plates, abrasion</li> </ul>	<ul style="list-style-type: none"> <li>• Martin Buehler, Sabrina Grannan, Tom Pike, Kim Kuhlman, Jason Feldman, Mike Hecht (791)</li> </ul>

# Carbon Nanotube Properties Relevant to NEMS

---

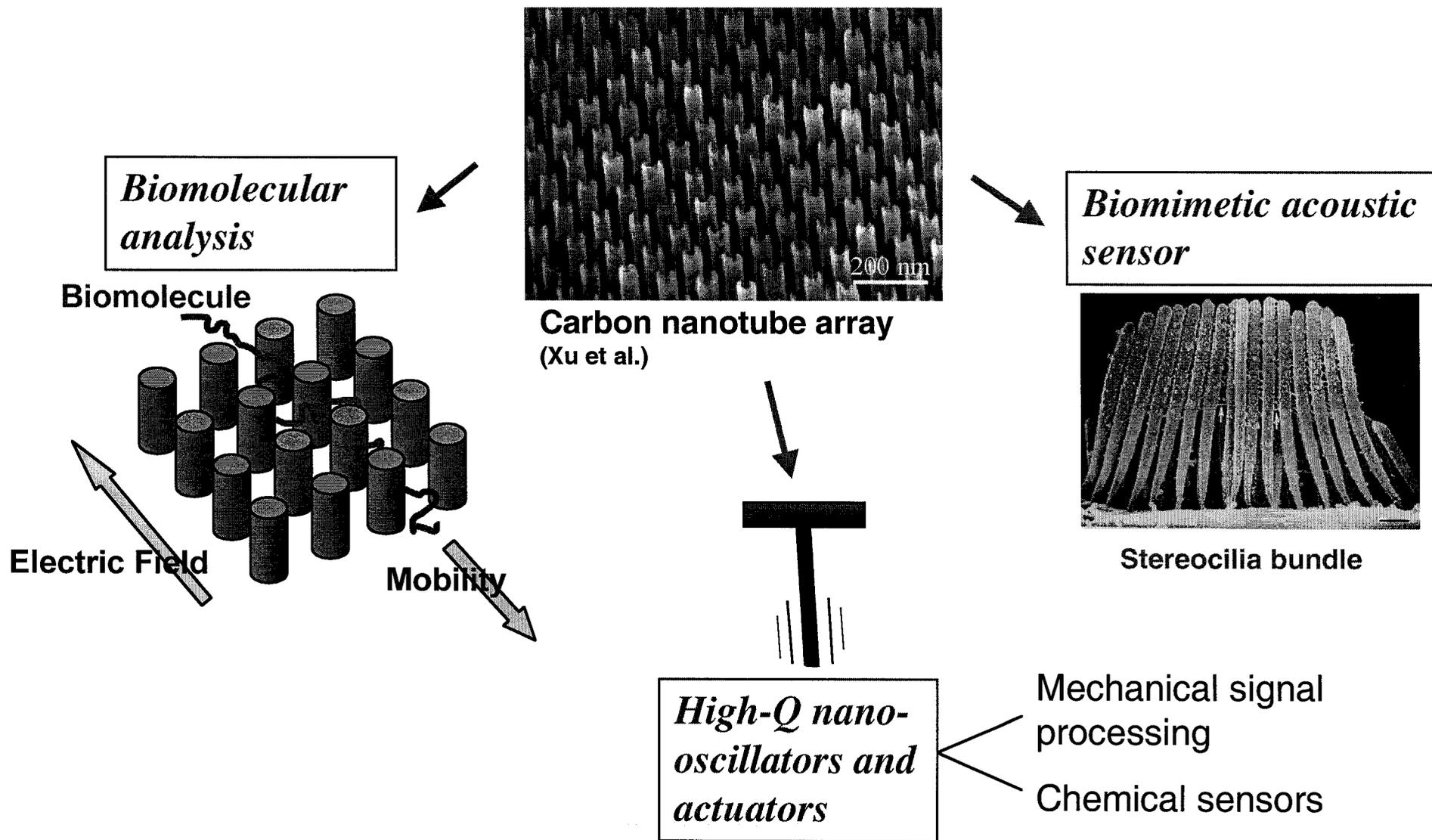
- ***Carbon nanotubes provide a novel combination of useful material properties and nanoscale dimensions not previously available***
- ✧ **Nanometer-scale diameter, high aspect ratio, and high electrical conductivity.**
  - Naturally at nanoscale dimensions needed for NEMS applications
  - 1-D nature may limit available states for energy loss - higher Q?
- ✧ **Exceptional strength/weight ratio (>200 times better than steel)**
- ✧ **High thermal conductivity (comparable to diamond).**
- ✧ **Charge-driven electromechanical actuation (work densities >25x higher than any other known technology)**
- ✧ **Highly uniform arrays possible**
  - Prof. Jimmy Xu



J.Xu et al.

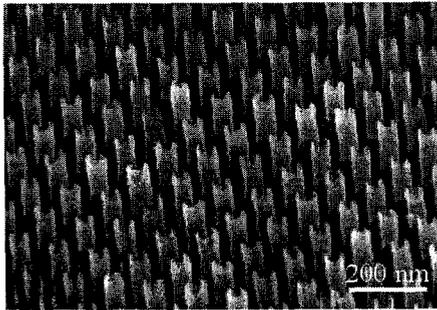
# Carbon Nanotube Array Applications

Flavio Noca, Dan Choi, Michael Hoenk, Brian Hunt, Bob Kowalczyk (JPL); Jimmy Xu (Brown U)

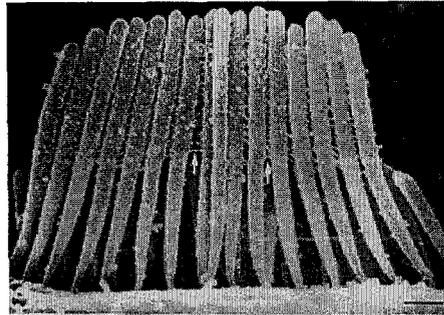


Michael Hoenk, Flavio Noca, Bob Kowalczyk, Dan Choi, Roger Williams, Brian Hunt (JPL); Jimmy Xu (Brown Univ.)

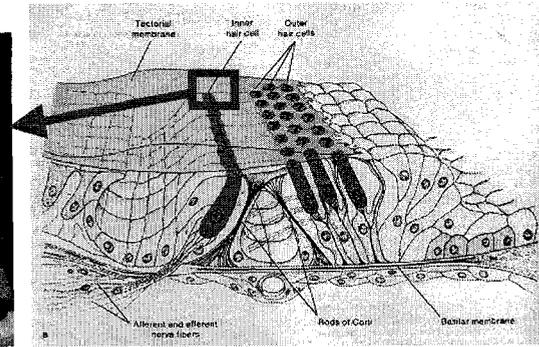
Combining biology and nanotechnology to achieve breakthroughs in sensitivity and miniaturization:



Carbon nanotube arrays  
(Xu et al.)

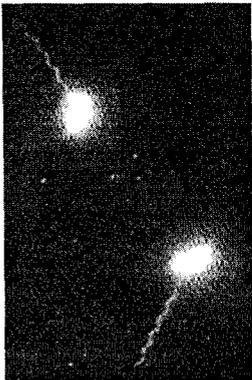


Stereocilia bundle  
in the cochlea

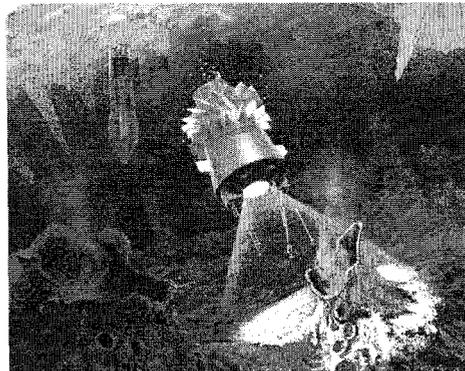


Cross-section of  
human cochlea

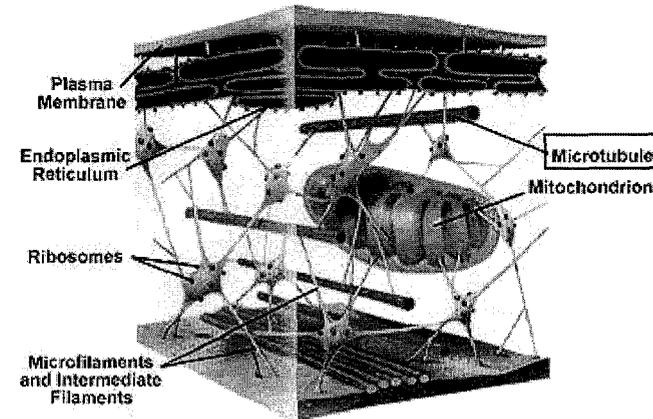
## • Applications



Listening to the  
Sounds of Life



Acoustic sounding in planetary  
atmospheres and oceans



Active or passive monitoring  
of cellular processes